

Image analysis as a basis to the design of wheelchair rugby sportswear

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Abstract

Sportswear clothing plays a very important part in athletes' performance. Inappropriate fit puts at risk not only the outcome of the sports event but also the safety of athletes. Wheelchair rugby is a good example of athletes wearing sportswear that is inappropriately fitted. The purpose of this study is to analyse, by means of videos and photographs, the patterns of activity and movements performed by the athletes during a set of wheelchair rugby training sessions. This analysis serves not only to inform on the movements and body postures but also on the problems and difficulties caused by the items of sportswear worn by the athletes. From the analysis it was observed that gloves are causing the most problems with performance, whilst tops and bottoms have more impact on comfort.

Keywords: body movement; clothing; gloves; inclusive design; mobility assistive devices.

1. Introduction

Research has shown that the fit of clothing is the most important and determinant factor for user satisfaction (LaBat and DeLong, 1990; Yu, 2004; Vinué *et al.*, 2014). Sportswear, as a specialised segment of the clothing industry, has its own fit requirements and challenges. In sportswear, fit is even more important as it is directly linked to performance and potentially to the outcome of the sports event (Gill and Prendergast, 2015).

While practising sports the body assumes a wide range of different postures that need to be accommodated by the garments worn (Watkins, 1995). As such, it is important that the clothing is designed to fit the users well throughout the full range of movement without compromising their performance (Vuruskan and Ashdown, 2017). Moreover, sportswear designs should not only take in consideration the entire structure of the body, including skeletal structure, muscle and fat deposition, but also the movements performed during the practice of each specific sport (Gill and Chadwick, 2009; Ashdown, 2011). Hence, appropriate designs should be derived from thorough analysis of patterns of activity and changes of body posture (Watkins and Dunne, 2015).

Clothing can also serve as a form of protection, and, for the sportswear segment, this is of paramount importance. In contact sports, such as the case of wheelchair rugby, having clothes with some sort of padding provides the only feasible source of protection (Watkins, 1977). Nonetheless, protection and freedom of movement is a combination that is not always achievable. On one hand, when the body is heavily protected, movement tends to be more difficult. On the other hand, when there are no constraints to the movements, it usually means that protection has been neglected (Watkins, 1977).

Nowadays, users' requirements for sportswear are stricter and more sophisticated. Users are expecting the garments to fit their body shape and size properly without restricting movements or

compromising comfort. With all the technological developments, it is now possible to bridge the gap between fit and function (Gill and Prendergast, 2015). However, for this to happen it is important to consider not only the design but also the materials used. The right choice of materials will allow improved performance, protection and comfort.

Wheelchair users have different needs in terms of clothing than able-bodied people. Garments should be adapted to their bodies shape and size and to their particular characteristics (e.g. underdeveloped lower body or difficulty of maintaining body temperature) (Curteza *et al.*, 2014). In sports, this is of particular importance as performance can be compromised if inappropriate garments are worn. However, due to the limited choice and availability of specialized garments, wheelchair users tend to adapt clothing designed for able-bodied people. In studies of wheelchair rugby this adaptation of garments has been found to happen very frequently (Bragança *et al.*, 2018). Bragança *et al.* (2018) found there are no specific sportswear for wheelchair rugby, which compromises the athletes' performance, comfort and safety.

The purpose of this paper is to understand how the garments that wheelchair rugby athletes are currently using can affect their performance during the practice of this sport. Furthermore, with this paper it is intended to define patterns of activity to identify the characteristics that a future garment should have in order to improve athletes' performance.

2. Methodology

2.1. Sample

The observations conducted for this study took place in the United Kingdom, on several training sessions of a wheelchair rugby team. The team observed is composed of approximately 25 athletes, however, the athletes' attendance is not constant, meaning that not all of them attended the same training sessions. Nonetheless, this allowed for a broader observation that included the analysis of a larger number of athletes.

Of the 17 athletes observed, 14 were males and only three were females. All of them had played for this particular team for more than one year.

2.2. Data collection and analysis

Videos and photographs were captured during several training sessions. These visual documents were complemented by notes also taken during the visits to the wheelchair rugby team. The team responsible for the observations was composed by a lead researcher and five students.

The videos and photographs taken were analysed individually to identify potential problems with the garments the athletes were wearing and their interaction with them. The movements and position of the body of each athlete was analysed in detail. The task analysis methodology was used to identify the different activities and movements undertaken by the athletes during training.

3. Results and Discussion

3.1. Main tasks and body positions

In this team, as happens for all other wheelchair rugby teams, athletes have two main types of positions in the game – they can play in an offensive or a defensive position. This position is a reflection of the athletes' function but it also reflects the type of wheelchair used. Offensive chairs,

meant for higher speed and mobility, have a front bumper and wings to prevent other wheelchairs from hooking it (used by athletes with more function). Defensive chairs, have front bumpers destined to hook and hold other players (used by athletes with less function).

Apart from these larger differences, the hand-rims on the wheelchair can also vary: the wheelchair used by this sample either had a metallic more prominent hand-rim or a plasticised flat hand-rim (Figure 1). The difference between hand-rims influences the interaction between the athletes' and the wheelchair as they move and position their hands differently according to the type of rim used. Unlike in other wheelchair sports, such as wheelchair-basketball, where the wheels are smooth and metallic, in wheelchair rugby the wheels are plasticised so they provide extra grip.



Figure 1 – Examples of (a) prominent metallic hand-rims and (b) flat plasticised hand-rims.

The results of the task analysis led to the identification of four main tasks undertaken by the athletes while on training sessions: (i) move forward and backward; (ii) change direction; (iii) slow down and stop; and (iv) throw or catch the ball. While performing each one of these tasks the athletes assume different postures. Moreover, each one of these tasks has a different impact on the different parts of the sportswear kit. Table 1 identifies the main body positions and its variations for these four tasks.

Table 1 – Main body positions and its variations for the four main tasks performed by athletes.

Task	Main body positions and variations
Move forward and backward	<ul style="list-style-type: none"> ▪ The upper body remains upright with the elbows slightly raised - OR - The upper body leans forward (for athletes with more function) ▪ The hands are placed at the top of the wheels at the start of the movement
Change direction	<ul style="list-style-type: none"> ▪ The upper body remains upright - OR - The upper body is leant to the side of the turn ▪ Both hands are in contact with the wheels - OR - Only one hand is placed on the wheel to provide maximum speed into the turn
Slow down and stop	<ul style="list-style-type: none"> ▪ The tips of the fingers are the major point of contact to slow down the wheels - OR - The palms of the hands are placed on the wheels at a 45° angle - OR - The forearms and elbows are used to exert pressure against the wheels to stop
Throw or catch the ball	<ul style="list-style-type: none"> ▪ The ball is caught with both hands ▪ The ball is thrown using normal rugby grip with both hands - OR - The ball is thrown using chest pass technique with fingers forming a W shape

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- The fingertips are used to force ball away from the body
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The following sub-sections provide more detail on how gloves, tops and bottoms affect the movements and positions assumed by the athletes during these tasks.

3.2. Impact on the design of gloves

By carefully observing the movements of each athlete, it was found that there are four different types of hand positions to move the wheelchair:

- a) Open hand, palm of the hand in contact with the wheels – Figure 2 (a);
- b) Hand closed in a fist – Figure 2 (b);
- c) Finger around the hand rim – Figure 2 (c);
- d) Back of the hand – Figure 2 (d).

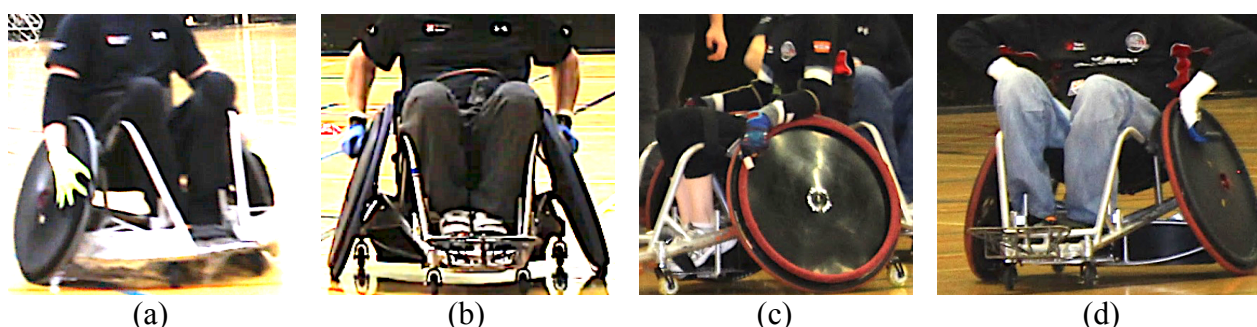


Figure 2 – Examples of the different positionings of the hand while moving the wheelchair.

The most common positions are (a) and (c). Pushing the wheelchair and catching/throwing the ball with the back of hand was found to be very uncommon, with only one athlete using this technique. To accommodate this user the design of the glove would have to be completely different, with padding on the back of the hand, rather than on the palm. For that reason, this athlete will not be considered for further analysis and discussion as they would need a completely personalised glove.

As has been found in a previous study (Bragança *et al.*, 2018), the gloves are the main problem with wheelchair rugby sportswear. One of the major problems with the gloves is that it is very difficult to secure them in place while manoeuvring the wheelchair during the game, which means that the athletes have to use tape around their wrists to secure the gloves. Moreover, every athlete needs to use rubber and/or glue to improve the grip of the gloves because, without this, the performance could put at risk.

When analysing the videos and photos, these problems were also present. The fact that athletes use tape to secure the gloves in place can also turn out to be a problem as it reduces the ability to move the wrist and do all the necessary movements. Moreover, the tape is used to provide extra grip and padding. However, it seems like this technique is not very efficient as, when braking, the momentum of the wheel keeps pulling the gloves off.

The skin on certain areas of the hand and elbow is constantly being grazed as the gloves and sleeves used do not provide enough padding and protection. Nonetheless, it is important to consider that thicker padding reduces the sensitivity of the hands, compromising performance. Many of the sleeves used by the athletes to protect the arms are inadequate – they are constantly sliding through the arms and in need of readjustment as can be seen of Figure 3.



(a)



(b)

Figure 3 – Example of sleeve sliding (a) as soon as the training starts and (b) after a few minutes.

Solutions for the design of gloves should firstly take in consideration the areas of the hand that are in more contact with the wheel and the ball – identified in Figure 4. These areas need some hard but not thick padding to prevent discomfort and injuries.

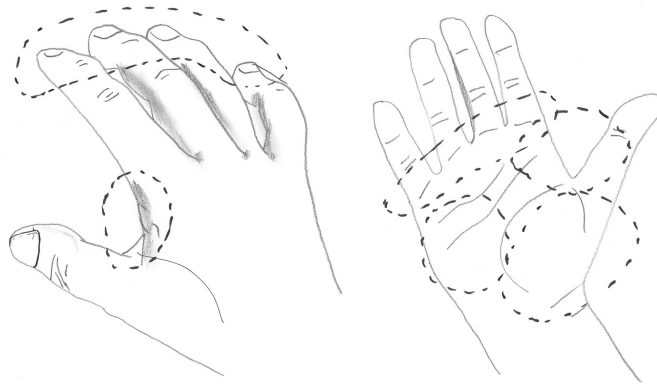


Figure 4 – Main areas of contact with the wheels and ball.

It would also be recommended that a sticky material is used on the tips of the fingers and some areas of the palm to provide more grip. A new way of securing the gloves in place should also be considered, either by having a longer cuff or by including a tight sleeve attachment that would also protect the forearms and elbows. Figure 5 shows examples of possible designs for the gloves.

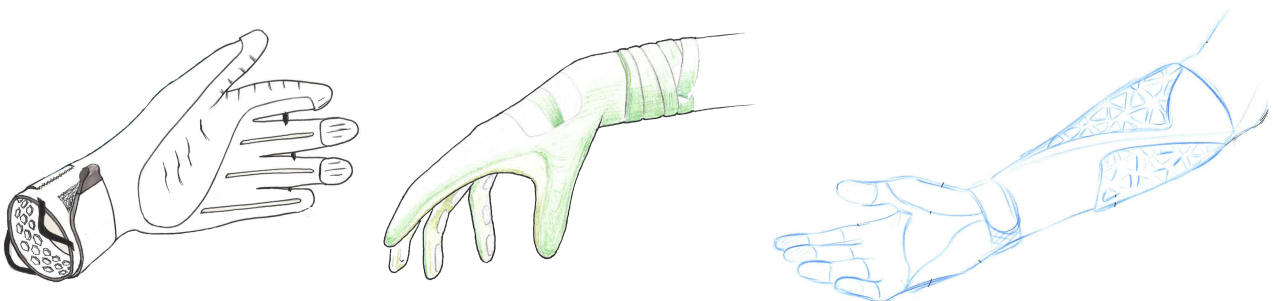


Figure 5 – Possible new design for wheelchair rugby gloves.

3.3. Impact on the design of tops and bottoms

The tops and bottoms are not as problematic as the gloves. Nonetheless, they still present a few challenges for the athletes.

The most common problems with the tops used by the athletes were mostly related to fit. Most athletes wear rounded neck tops that sit too high on the neck. As previously mentioned, when pushing the wheelchair forward, some of them lean their upper body to the front, increasing the pressure exerted by the shirt on the neck and causing discomfort (Figure 6 (a)). Moreover, when leaning forward, the back of the top is pulled up, not only restricting movements but also leaving the back uncovered and open to rubbing against the chair (Figure 6 (b)).



Figure 6 – Examples of problems with the tops.

A potential solution for these problems on the neck area would be having a more elasticated neck opening that would provide more flexibility and an increased range of motion. Modification to the positioning of the neck opening within the pattern block may also be of benefit, reflecting the position of a seated wearer. For the problem of the back, it would be recommended to have tops that have longer backs provided that this would not prevent the athletes from performing all the necessary movements. A longer top may be trapped against the athlete and chair and rather than riding up (slip) the fabric characteristics (stretch) would retain coverage, whilst permitting this movement.

The majority of the bottoms worn by the athletes were not observed to negatively influence the ability to perform certain tasks or movements. The problems with the bottoms mostly relate to fit and comfort. According to a previous study conducted by the authors (Bragança *et al.*, 2018), the most common problems wheelchair rugby athletes have with the bottoms are:

- Too tight or too loose in some areas;
- Loose trousers get caught on wheels and push rims;
- Are not adapted to body shape and size;
- Lower back is visible;
- Accumulation of excess fabric in the waist and back of the knee areas causes discomfort;
- Thick and hard seams cause abrasion.

By analysing the videos and photographs taken for this study, it was possible to verify the occurrence of these exact problems. Figure 7 shows examples of problems with the length of the bottoms used. Shorts that are too short cause contact and rubbing between the skin and the chair, which, after the entire two-hour training session can prove to be uncomfortable (Figure 7 (a)). On the other hand, slightly longer shorts, which touch the back of the knee can also be uncomfortable as they are usually too tight (Figure 7 (b)). Regarding trousers, even when they are appropriate for practising sports, they

are not adapted to the sitting position. This means that there is an accumulation of excess fabric on the front which is not only uncomfortable but also increases the skin temperature on that area (Figure 7 (c)).

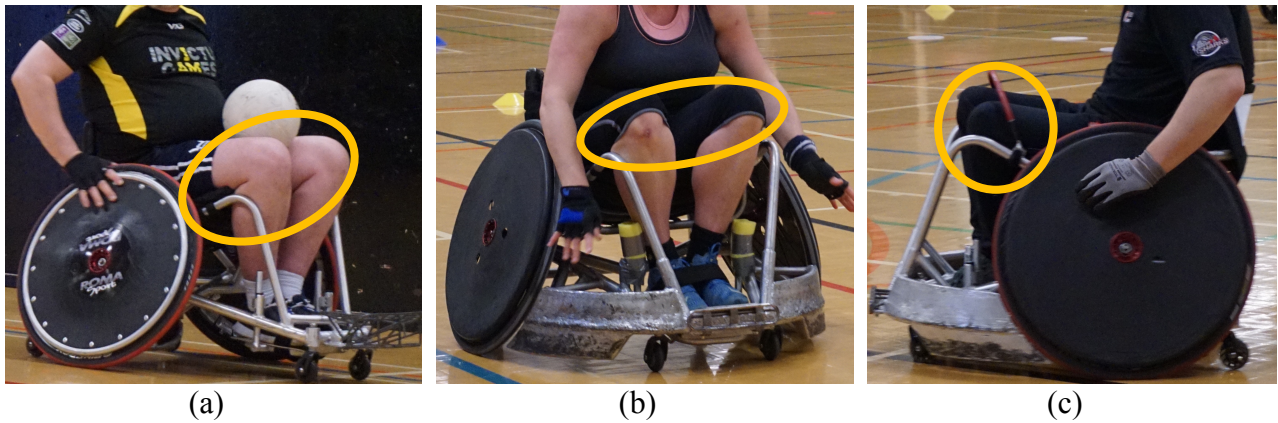


Figure 7 – Examples of problems with the length of the bottoms used.

The majority of these problems could be solved by implementing some changes to the patterns used for traditional trousers. Some of the same strategies used by other already existing products (Carvalho *et al.*, 2015), could also be put into practice in trousers for wheelchair rugby. These changes in the design allow for sitting comfortably during long periods of time by taking in consideration the ergonomics of this position (Figure 8).

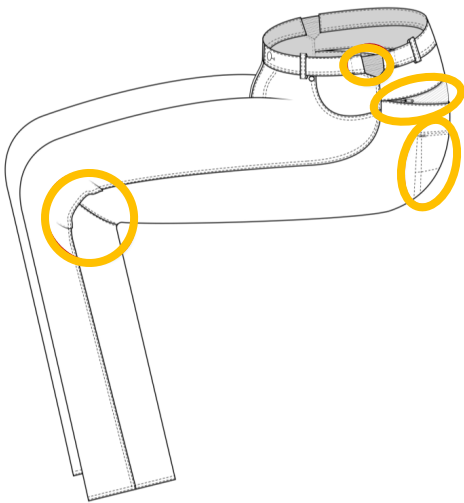


Figure 8 – Representation of the modifications included in specialised jeans (REF).

Some of these changes that could be useful for wheelchair rugby include (i) the removal of excess fabric accumulated on the back of the knee when the user assumes the sitting position; (ii) the inclusion of an extendable waistband that grows in accordance with the changes in posture; and (iii) the modification of the back seat area, providing a higher rise of the trousers on the back and a lower rise on the front.

4. Conclusions

The analysis of several images, both from videos and photographs taken during a set of wheelchair rugby training sessions allowed a clear understanding of the main tasks necessary for this sport and the principal body movements and postures assumed by the athletes. Moreover, this analysis helped to develop a detailed understanding of how the clothing worn by the athletes during the training session impacts on their performance and wellbeing.

Gloves were identified to be the main cause of problems in athletes' performance, whereas tops and bottoms influence comfort the most. Solutions for the gloves could include the addition of a sticky material over the finger tips and part of the palm to provide more grip; the inclusion of a sleeve to protect the forearms and elbows; and the modification of the existent wrist cuff. To improve the comfort of the tops, it would be important to change the neck opening, so that it does not compress the skin, and to increase the length of the top on the back area, so that skin is not exposed. For bottoms, and especially for full trousers, it would be recommended to remove the excess fabric that is accumulated on the back of the knee through modifications to the pattern.

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